

We claim:

- 1 1. A microsensor for sensing a substance comprising:
2 a substrate;
3 a source of light;
4 an optical microresonator fabricated in the substrate exposed to the
5 substance to allow an interaction between the microresonator and substance;
6 a waveguide coupling the source of light to the optical microresonator; and
7 a detector coupled to the microresonator to measure a performance
8 parameter of the optical microresonator sensitive to interaction of the substance
9 with the optical microresonator.

- 1 2. The microsensor of claim 1 further comprising a polymer coating disposed
2 on the microresonator, which polymer coating is reactive with the substance.

- 1 3. The microsensor of claim 1 where the microresonator is a semiconductor
2 optical ring microresonator.

- 1 4. The microsensor of claim 1 where the microresonator has an initial Q of
2 10,000 or greater.

1 5. The microsensor of claim 1 where the performance parameter is the
2 resonant frequency of the microresonator.

1 6. The microsensor of claim 1 where the performance parameter is the
2 absorption loss of whispering gallery modes in the microresonator.

1 7. The microsensor of claim 1 where the performance parameter is the
2 quality factor of the microresonator.

1 8. The microsensor of claim 1 where the detector is a germanium detector
2 and the substrate is a silicon-on-insulator (SOI) heterostructure.

1 9. The microsensor of claim 8 further comprising CMOS integrated read-out
2 circuitry fabricated in the substrate and coupled to the germanium detector.

1 10. The microsensor of claim 1 where the detector comprises a read-out optic
2 fiber coupled to a grating coupler.

1 11. The microsensor of claim 1 further comprising a plurality of
2 microresonators and a corresponding plurality of detectors formed into an array
3 coupled by the waveguide to the light source in which the plurality of
4 microresonators are exposed to a plurality of substances.

1 12. The microsensor of claim 11 further comprising an addressing circuit for
2 reading the array.

1 13. The microsensor of claim 12 further comprising CMOS integrated read-out
2 circuitry fabricated in the substrate coupled to the addressing circuit.

1 14. The microsensor of claim 1 where the detector comprises a polycrystalline
2 germanium detector fabricated proximate to the microresonator.

1 15. The microsensor of claim 1 where the detector is deposited onto the
2 waveguide during a post-processing step following CMOS fabrication of the
3 waveguide.

1 16. The microsensor of claim 1 further comprising a microfluidic circuit for
2 communicating the substance to the microresonator.

1 17. The microsensor of claim 16 where the microfluidic circuit comprises
2 pneumatic valves and peristaltic pumps defined by multi-layer replication
3 lithography for delivering picoliter volumes of the substance to the
4 microresonator.

1 18. The microsensor of claim 1 where the microresonator is characterized by
2 an optical absorption loss determined by direct optical excitation of the substance
3 when in contact with the microresonator.

1 19. The microsensor of claim 18 further comprising a plurality of
2 microresonators corresponding to a plurality of different resonant frequencies to
3 generate an absorption spectrum of the substance.

1 20. The microsensor of claim 2 where the coating reacts with the substance to
2 form an altered optical parameter which in turn alters an optical parameter of the
3 microresonator.

1 21. The microsensor of claim 20 where the altered optical parameter is the
2 refractive index of the coating or the waveguide loss of the microresonator.

1 22. The microsensor of claim 20 where the coating reacts only with the
2 substance.

1 23. The microsensor of claim 22 where the coating is reacts only with the
2 substance by means of an enzyme linked immunosorbent assay (ELISA).

1 24. The microsensor of claim 2 further comprising a microfountain pen and
2 where the coating is applied to the microresonator by the microfountain pen.

1 25. The microsensor of claim 2 further comprising an elastomeric flow channel
2 in communication with the microresonator and where the coating is applied to the
3 microresonator by a functionalization treatment by means of the elastomeric flow
4 channel.

1 26. The microsensor of claim 1 further comprising a plurality of microsensors
2 organized in an addressable array on the substrate, ones of the plurality of
3 microsensors being resonant at or tuned to different optical frequencies,
4 absorption losses of the plurality of microsensors being measured as a result of
5 optical coupling between an analyte and ones of the resonators as determined by
6 the resonant frequency of the microresonator and the absorption peak of the
7 analyte, whereby an absorption spectrum of direct spectroscopy of an analyte or
8 absorption of antibody-linked fluorescent molecules used as markers are
9 measured.

1 27. The microsensor of claim 1 further comprising a plurality of microsensors
2 organized in an addressable array on the substrate, the plurality of corresponding
3 resonators having a selectively pretreated surface, a change in refractive index
4 or waveguide loss of ones of the plurality of resonators arising as a result of
5 selective attachment of an analyte to the pretreated surface being measured.

1 28. The microsensor of claim 1 where the substrate is a silicon-on-insulator
2 (SOI) substrate, where the waveguide and microresonator are fabricated on the
3 substrate by means of SOI processes and where the detector is fabricated on the
4 substrate by means of CMOS fabrication processes.

1 29. The microsensor of claim 1 where the source of light comprises an
2 external laser.

1 30. The microsensor of claim 1 where the source of light comprises a filtered
2 tungsten filament lamp, a filtered broad-band light emitting diode, a Fabry-Perot
3 cleaved cavity laser, a vertical cavity surface emitting (VeSEL), or a grating
4 coupled surface emitting laser directly bonded onto the substrate.

1 31. The microsensor of claim 13 where the CMOS integrated read-out circuitry
2 provides diagnostic information on the condition of sensor performance and
3 electronic intelligence in the read-out process.

1 32. The microsensor of claim 31 further comprising a wireless interface
2 fabricated on the substrate and communicated to the read-out circuitry.

1 33. A method for sensing a substance comprising:
2 providing a substrate;

3 providing a source of light;
4 communicating the light through a waveguide coupled to the source of
5 light to an optical microresonator fabricated in the substrate exposed to the
6 substance to allow an interaction between the microresonator and substance;
7 and
8 detecting the interaction between the microresonator and substance by
9 measurement of a performance parameter of the optical microresonator.

1 34. The method of claim 33 further comprising disposing a polymer coating on
2 the microresonator, which polymer coating is selectively reactive with the
3 substance.

1 35. The method of claim 33 where detecting the interaction between the
2 microresonator and substance comprising detecting the optical performance of a
3 semiconductor optical ring microresonator.

1 36. The method of claim 35 where detecting the optical performance of a
2 semiconductor optical ring microresonator comprises measuring the optical
3 performance of a microresonator with an initial Q of 10,000 or greater.

1 37. The method of claim 36 where measuring the optical performance of a
2 microresonator comprises measuring the resonant frequency of the
3 microresonator.

1 38. The method of claim 36 where measuring the optical performance of a
2 microresonator comprises measuring the absorption loss of whispering gallery
3 modes in the microresonator.

1 39. The method of claim 36 where measuring the optical performance of a
2 microresonator comprises measuring the quality factor of the microresonator.

1 40. The method of claim 33 where detecting the interaction between the
2 microresonator and substance comprises detecting the optical output of the
3 microresonator with a germanium detector and where providing the substrate
4 comprises providing a silicon-on-insulator (SOI) heterostructure.

1 41. The method of claim 33 further comprising fabricating CMOS integrated
2 read-out circuitry in the substrate corresponding to each microresonator.

1 42. The method of claim 33 where detecting the interaction between the
2 microresonator and substance comprises coupling light from the microresonator
3 to a read-out optic fiber coupled to a grating coupler.

1 43. The method of claim 33 further comprising providing a plurality of
2 microresonators and a corresponding plurality of detectors configured into an
3 array coupled by the waveguide to the light source and exposing the plurality of
4 microresonators to the substance or plurality of substances.

1 44. The method of claim 43 further comprising fabricating an addressing
2 circuit on the substrate for reading the array.

1 45. The method of claim 44 further comprising fabricating CMOS integrated
2 read-out circuitry in the substrate coupled to the addressing circuit.

1 46. The method of claim 33 where detecting the interaction between the
2 microresonator and substance comprises detecting the interaction with a
3 polycrystalline germanium detector fabricated proximate to the microresonator.

1 47. The method of claim 46 further comprising fabricating the waveguide with
2 CMOS processes and fabricating the detector in communication with the
3 waveguide during a post-processing step following CMOS fabrication of the
4 waveguide.

1 48. The method of claim 33 further comprising providing a microfluidic circuit
2 for communicating the substance to the microresonator.

1 49. The method of claim 48 where providing a microfluidic circuit comprises
2 fabricating pneumatic valves and peristaltic pumps by multi-layer replication
3 lithography for delivering picoliter volumes of the substance to the
4 microresonator.

1 50. The method of claim 33 where detecting the interaction between the
2 microresonator and substance comprises measuring an optical absorption loss of
3 the microresonator arising from direct optical excitation of the substance when in
4 contact with the microresonator.

1 51. The method of claim 50 further comprising detecting the interaction
2 between the microresonator and substance at a plurality of microresonators
3 corresponding to a plurality of different resonant frequencies to generate an
4 absorption spectrum of the substance.

1 52. The method of claim 34 further comprising selectively reacting the coating
2 with the substance to alter an optical parameter of the microresonator.

1 53. The method of claim 52 where reacting the coating with the substance
2 comprise altering the refractive index of the coating or the waveguide loss of the
3 microresonator.

1 54. The method of claim 52 where selectively reacting the coating with the
2 substance comprises reacting only with the substance.

1 55. The method of claim 54 where reacting only with the substance comprises
2 reacting only with the substance by means of an enzyme linked immunosorbent
3 assay (ELISA).

1 56. The method of claim 34 further comprising applying the coating to the
2 microresonator by means of a microfountain pen.

1 57. The method of claim 34 further comprising applying the coating to the
2 microresonator by means of an elastomeric flow channel in communication with
3 the microresonator.

1 58. The method of claim 33 further comprising providing a plurality of
2 microsensors organized in an addressable array on the substrate, ones of the
3 plurality of microsensors being resonant at or tuned to different optical
4 frequencies, measuring the absorption losses of the plurality of microsensors as
5 a result of optical coupling between an analyte and ones of the resonators as
6 determined by the resonant frequency of the microresonator and the absorption
7 peak of the analyte, and generating an absorption spectrum of direct

8 spectroscopy of an analyte or absorption of antibody-linked fluorescent
9 molecules used as markers are measured.

1 59. The method of claim 33 further comprising providing a plurality of
2 microsensors organized in an addressable array on the substrate, the plurality of
3 corresponding resonators having a selectively pretreated surface, changing the
4 refractive index or waveguide loss of ones of the plurality of resonators as a
5 result of selective attachment of an analyte to the pretreated surface and
6 measuring the change the refractive index or waveguide loss to generate an
7 assay of the substance.

1 60. The method of claim 33 where providing the substrate provides a silicon-
2 on-insulator (SOI) substrate, and further comprising fabricating the waveguide
3 and microresonator on the substrate by means of SOI processes and fabricating
4 the detector on the substrate by means of CMOS fabrication processes.

1 61. The method of claim 33 where providing the source of light comprises
2 providing an external laser.

1 62. The method of claim 33 where providing the source of light comprises
2 providing a filtered tungsten filament lamp, a filtered broad-band light emitting
3 diode, a Fabry-Perot cleaved cavity laser, a vertical cavity surface emitting

4 (VeSEL), or a grating coupled surface emitting laser directly bonded onto the
5 substrate.

1 63. The method of claim 45 further comprising generating diagnostic
2 information on the condition of sensor performance and electronic intelligence by
3 means of the integrated read-out circuitry.

1 64. The method of claim 45 further comprising fabricating a wireless interface
2 on the substrate communicated to the read-out circuitry.